DESIGN AND ANALYSIS OF FRACTAL ANTENNA FOR WIRELESS APPLICATION

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF

BACHELOR OF TECHNOLGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

BY

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CERTIFICATE

This is to certify that the thesis entitled, "**Design and Analysis of fractal antenna for wireless application**" submitted by **Mr. Hari Jenna** is a record of an original research work carried out by him under my supervision and guidance in partial fulfilment of the requirements for the award of the degree of **Bachelor of Technology** in **Electronics and Communication Engineering** at the **National Institute of Technology, Rourkela**.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any degree or diploma.

DATE: 12-05-2014

Dr. S. K. Behera

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ABSTRACT

In future the growth of telecommunication systems plays a major role in daily life. So one has to design a antenna with lower weight, wide bandwidth, smaller dimension and cheap in cost than conventionally possible. This has initiated a research about antennas in various directions, and it is found that the following requirements can be achieved by using fractal shaped antenna.

In the present thesis a plus shaped fractal antenna is designed. This design is particularly focused on generation of multi frequency which results in increased bandwidth and size reduction of the antenna and have better characteristics when compared with conventional microstrip antenna. Fractal antennas are described by space filling and having self similar properties. They show multiband characteristics because of their self similar properties. All antennas are designed on a substrate taking dielectric constant €r = 4.4 and thickness 0.05 mm, and a 50 ohm SMA connector is used to feed the antenna.

The fractal antenna characteristics with slot and with iterations are simulated using CST Microwave Studio Suite 12. Finally, in this type of antenna if we go on changing the Length of the slot Ls which results in reduction of resonant frequency from 2.48Ghz to 1.01Ghz. Thus corresponding to about a size reduction of 59.27% and increased bandwidth of 14.38 % after two iterations are successfully attained.

CHAPTER 1

THESIS OVERVIEW

1.1 INTRODUCTION

Wireless refers to the transport of information signals without using wires. Now a days it is one of the most blooming areas in the communication field today I think the most commonly used wireless technologies is radio. Wireless operations allow skills, such as distant communications, that are tough or speculative to implement with the use of wires and costs a lot. In numerous homes and offices, the mobile phones free us from the short leash of handheld cords. Cell phones give us even more freedom such that we can communicate with each other at any place and at any time. These wireless phones use radio waves to enable their users to make phone calls from many locations worldwide. Antenna is one of the most important use for wireless communication. Now a days it’s dominating in the field of mobile communication i.e wireless communication. About antennas, it is described in the next coming lines.

Antennas are basic components of any electric system and are connecting links between transmitter and free space (or) free space and the receiver. Thus antennas play very important role in finding the characteristics of the system in which antennas are employed. Antennas are employed in different systems in different forms. That is, in some systems the operational characteristic of the system are designed around the directional properties of the antennas or in some others systems, the antennas are used simply to radiate electromagnetic energy in an omnidirectinal orfinally in some systems for point-to-point communication purpose in increased gain and reduced wave interference are required.

I found that in the study of antennas, **fractal antenna** theory is a relatively new area. The term “fractal” means broken or irregular fragments. It was defined by a great man Mandelbrot to describe a family of complex shapes that possess an inherent self-similarity or self-affinity in their geometrical structure.. One of the most promising area fractal electrodynamics re-searches is in its application to antenna theory and design. There are varieties of approaches that have been developed over the years, which can be put into service to archive one or more of these design objectives. The development of fractal geometry came largely from an in depth study of the pattern nature, with the advance of wireless communication system and their increasing importance wide band and low profile antennas are in great demand for both commercial and military applications.

1.2 THESIS MOTIVATION

In the world of modern telecommunication systems requires antennas with wide bandwidth, low profile antennas, small size, low cost, high performance and can be used for more wireless applications such as WLAN, Wifi systems, GSM services, GPS services. To meet this requirements fractal antenna is came into existence. Providing with high bandwidth, increasing reduction percentage of antenna. In this thesis a plus shape fractal antenna is designed up to 2^{nd} iteration. After the second iteration, if we move on to third iteration, complexity increases. So up to 2^{nd} iteration it is designed. Other disadvantages are low gain, low power handling capability, high Q value and polarization purity. Most important factor is that the antennas should be well impedence matched over the operating frequency range. In recent years, there is to be used antennas with wider bandwidth and smaller dimension rather than conventional one.

Fractal antennas have advantages such as small volume, low manufacturing cost and easy integration. These are implemented in the planar microstrip antenna geometry. Size can be reduced to two or four times with surprising fair performance. Multiband performance can be achieved further.

CHAPTER 2

MICROSTRIP ANTENNAS

2.1 Microstrip Antenna (MSA)

Microstrip antennas are designed to meet the requirements such as high performance aircraft, spacecraft, satellite, and missile applications, where small size, low weight, cheap, high performance, easy installation, where low profile antennas are required . one of the low profile antennas may be microstrip antennas. The idea of **Microstrip antenna** can be traced to 1953 and a patent in 1955. It received considerable attention starting in the 1970s. These antennas are low profile, conformable to planar and nonplanar surfaces, simple and not expensive to manufacture, mechanically robust when it is mounted on rigid surfaces, compatible with MMIC designs and when the particular patch shape and mode are selected, they are versatile in fields of resonant frequency, pattern, polarization, impedence.

Coming to its structure, The top and side views of a rectangular Microstrip antenna are shown in Fig. 2.1. Often microstrip antennas are also known as patch antennas. Top view consist of a very thin metallic strip placed a small fraction of a wave length above a ground plane. It is designed in such a way that the pattern maximum is normal to the patch. For a rectangular patch, the length L of a given element is $\lambda 0/3 < L < \lambda 0/2$. The patch and ground plane are disjoined by a substrate, it is shown in the figure 2.1 The radiating elements and feed lines are usually photoetched on on the dilelectric substrate. The radiating patch may be square, circular, triangular, semi-circular, sectoral, and annular ring shapes shown in Fig. 2.2. They are easy to fabricate and their absorptive radiation characteristics, particularly they have low cross polarization radiation. Microstrip dipoles are known as attractive because they occupy large bandwidth and pocess less space. By using either single elements or arrays of MSA, linear polarization and circular polarization can be accomplished.

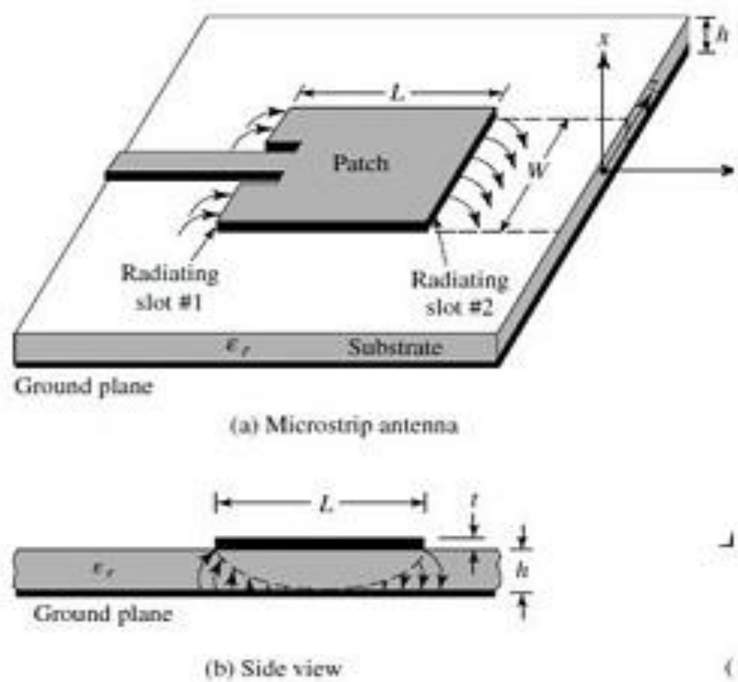


Figure 2.1 Microstrip antenna with its side view

There are plentiful substrates which can be used for the design of microstrip antennas, and their dielectric constants are commonly in the range of 2.2 to 12. Thick substrates are the ones that are most worthy for antenna performance whose dielectric constant is in the lower end of the range because they provide better efficiency, larger bandwidth, loosely bound fields for radiation into space, but at the expense of larger element size. Thin substrates which have high dielectric constants are desirable for microwave circuitry because they require tightly bound fields to minimize undesired radiation and coupling, and lead to smaller element sizes; however, because their greater losses, they are less efficient and have relatively smaller bandwidths. Since MSA are often integrated with other microwave circuitry, a agreement has to be reached between good antenna performance and circuit design.

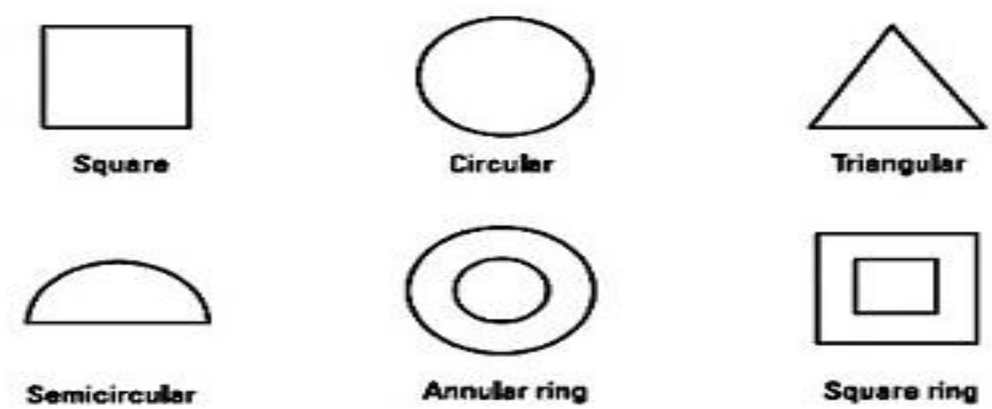


Figure 2.2 Several shapes of microstrip patches

2.2 Feeding methods

There are many feeding methods that can be used to feed microstrip antennas. The four most popular techniques are microstrip line, coaxial-line feeds, aperture coupling and proximity coupling .

Microstrip antenna by a microstrip line on the same substrate appears to be a natural choice because patch can be an extension of microstrip line and both can be easily fabricated simultaneously. The **microstrip feed line** is also known as conducting strip, it has much smaller width when it is compared with the patch. Its easy to fabricate and simple to match by controlling the inset position and rather simple to model. As the substrate thickness increases surface waves and spurious feed radiation also increases, which for practical designs limit the bandwidth is typically 2-5%. A microstrip feed line and its equivalent circuit are shown in Figs. 2.3 a and 2.3 b, respectively.

In **coaxial-line feeds**, where the inner conductor of the coax is attached to the radiation patch and the outer conductor is connected to the ground plane, are also widely used. The coaxial probe feed, easy to fabricate and match, and it has low spurious radiation. However, it also has keenly bandwidth, especially for thick substrates, coaxial probe is much difficult to model. A typical coax feed and its equivalent circuit are also shown in Figs. 2.4 a and 2.4 b , where its inner conductor is attached to the patch and outer is connected to the ground plane.

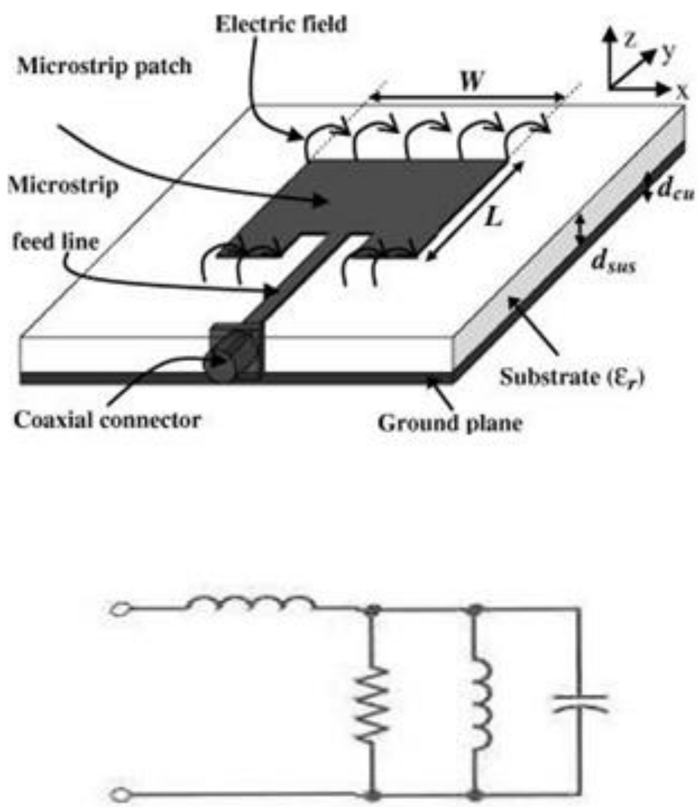
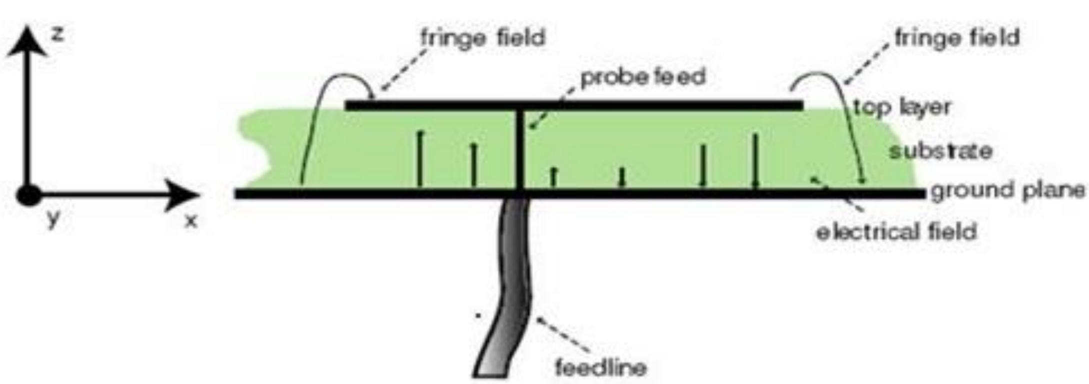


Figure 2.3 a) Microstrip line feed b) Equivalent circuit of microstrip feed line



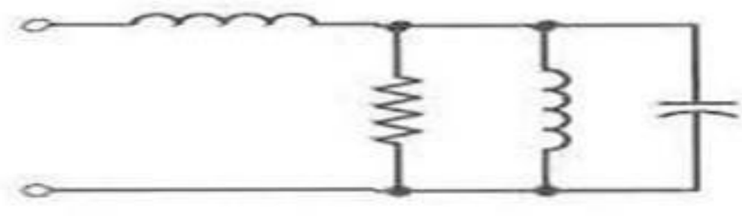
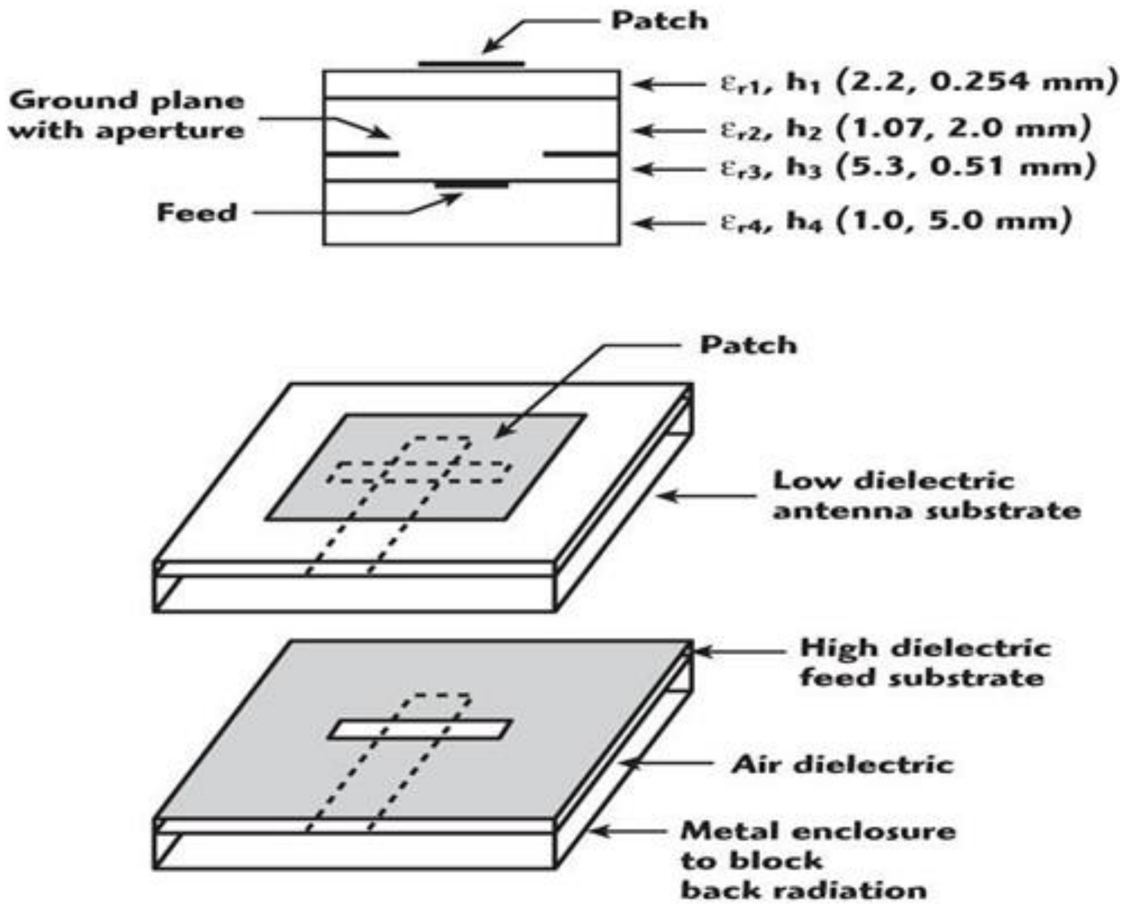


Figure 2.4 a) Coxial line feed 2.4 b) Equivalent circuit of coaxial feed line.

Third technique, **Aperture coupling** consists of a two layer substrate separated by a ground plane, with the microstrip line on the bottom layer whose energy is coupled to patch through a slot on the ground plane separating the two substrates as shown in the figure 2.5a And its equivalent circuit is shown by Fig. 2.5b. This arrangement allows independent optimization of the feed mechanism and the radiating element. The ground plane in between the substrates is to obtain the feed from the radiating element and reduces interferences of the spurious radiation for pattern formation and polarization purity. Typically for the bottom substrate a high dielectric material is used, and thick low dielectric constant material for the top substrate. For this design, the substrate electrical parameters, feed line width, and slot size and position can be used to design the best one. Typically matching is performed by controlling the width of the feed and the length of the slot.



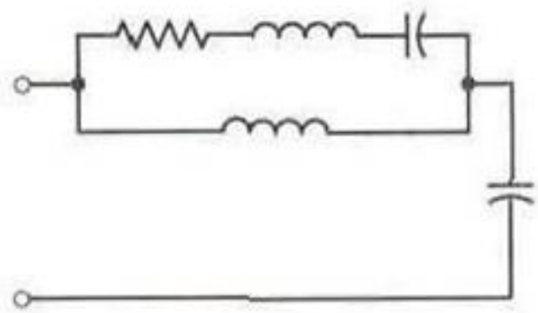


Figure 2.5a Aperture coupled feed & 2.5b Typical Equivalent circuit of aperture coupled feed

Fourth technique, **Proximity Coupled feed,** it uses a two layer substrate with the microstrip line on the bottom layer and patch antenna on the upper layer. This feed is also known as an “Electromagnetically coupled ” microstrip feed. Its easy to model, it has the highest bandwidth, and has low spurious radiation.

Of the four methods elaborated here, the proximity coupling has the highest bandwidth. The most rigurous demerit of microstrip antennas is their small bandwidth. As microstrip antennas are having small bandwidth, so there is need to have some method to increase its bandwidth. The most advantageous methods is by proximity coupling. There are two types of bandwidths, one is impedence bandwidth i.e the bandwidth over which the antenna remains matched to the feed line to some specified level, such as VSWR , and the pattern bandwidth i.e the bandwidth over which the pattern remains, in some sense, constant. The ideal broadband element will satisfy both the criteria.

The corresponded bandwidth is obtained by using a microstrip feed line proximity-coupled to a patch antenna printed on a substrate above the feed line as shown in Fig.2.6 a. The typical equivalent circuit of Proximity coupled feed is shown in Fig.2.6 b. The length of the feeding stub and the width to line ratio of the patch can be used to control the match.

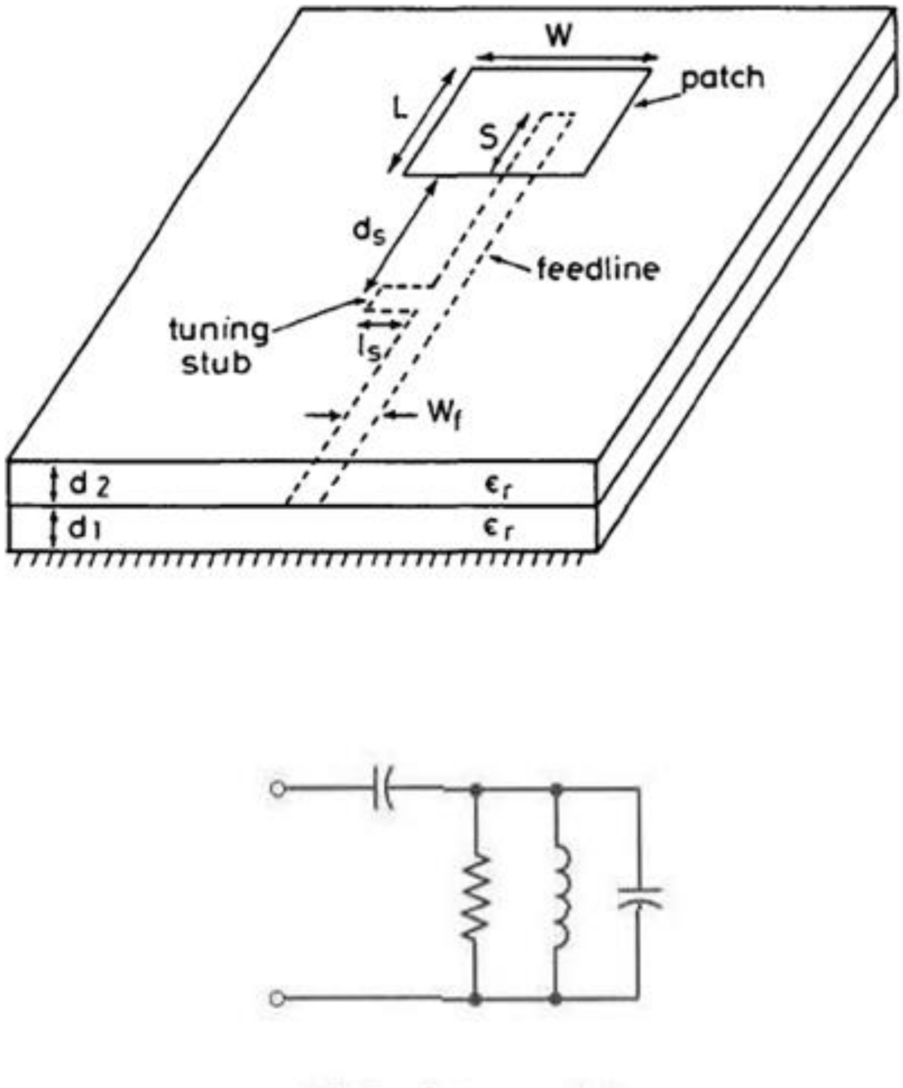
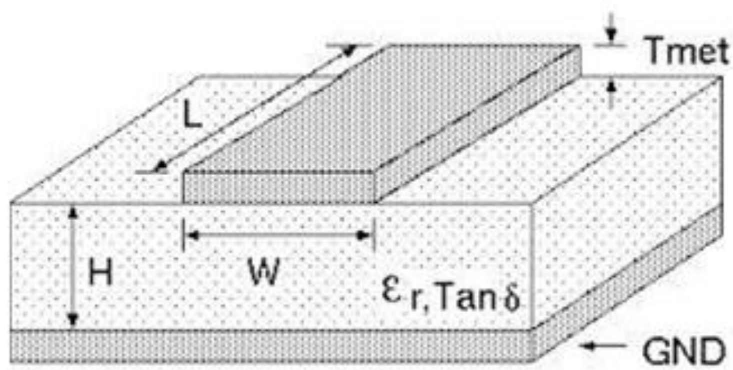


Figure 2.6a) Proximity coupling feed   2.6b) equivalent circuit

2.3 <u>Different Methods of Analysis for MSA</u>

There are different methods for the analysis of MSA. One of easiest method is **transmission line**, other than this there are cavity and full wave. It is less accurate and it is difficult to model. Fundamentally the model represents the microstrip antenna by two slots spaced a part by a low-impedance transmission line of length L, height h and width W as shown below figure.



2.4 Fringing Effects

As we know that the dimensions of the patch are bounded along the length L and width W, at the edges of the patch the fields undergo fringing. This is clarified in Fig 2.1 for the two radiating slots of the microstrip antenna. The quantity of fringing is a function of the height of substrate and the dimensions of the patch. A microstrip line, and its typical electric field lines are illustrated in Fig.2.8. This is a non homogenous line of two dielectrics; typically the substrate and air. As it can be observed from the diagram, extremely the electric field lines reside in the substrate and parts of some lines exist in air. As $W/h>>1$ and $\epsilon_r>>1$, the electric field lines concentrate much on the substrate. In this case Fringing makes the microstrip line look wider electrically compared to its physical dimensions. Since some of the waves travel in the substrate and other travel in air, an **effective dielectric constant** ϵ_{reff} is came in to account for fringing and the wave propagation in the line.

For a line with air above the substrate, effective dielectric constant ϵ_{reff} has the values in the range of 1 to ϵ_r . It depends on frequency of operation also. As the operating frequency increases, most of the electric field lines concentrate in the substrate. The dielectric constant of the substrate is much greater than unity ($\epsilon_r >>1$) f or most of the applications, the evaluation of ϵ_{reff} will be closer to the value of the actual dielectric constant of the substrate.

EDC ϵ_{reff} is nearly constant for low frequencies. At the intermediate frequencies its values begin to increase slowly and ultimately approach the values of the dielectric constant of the substrate. The initial value at low frequency of EDC are also known as static values are given by Eq. 2.1. This value is valid for W/h.

$$\epsilon_{reff} = (\epsilon_r + 1)/2 + (\epsilon_r - 1)/2 \; [1/\sqrt{(1 + 12\, h/W)}] \quad ------------------------ (2.1)$$

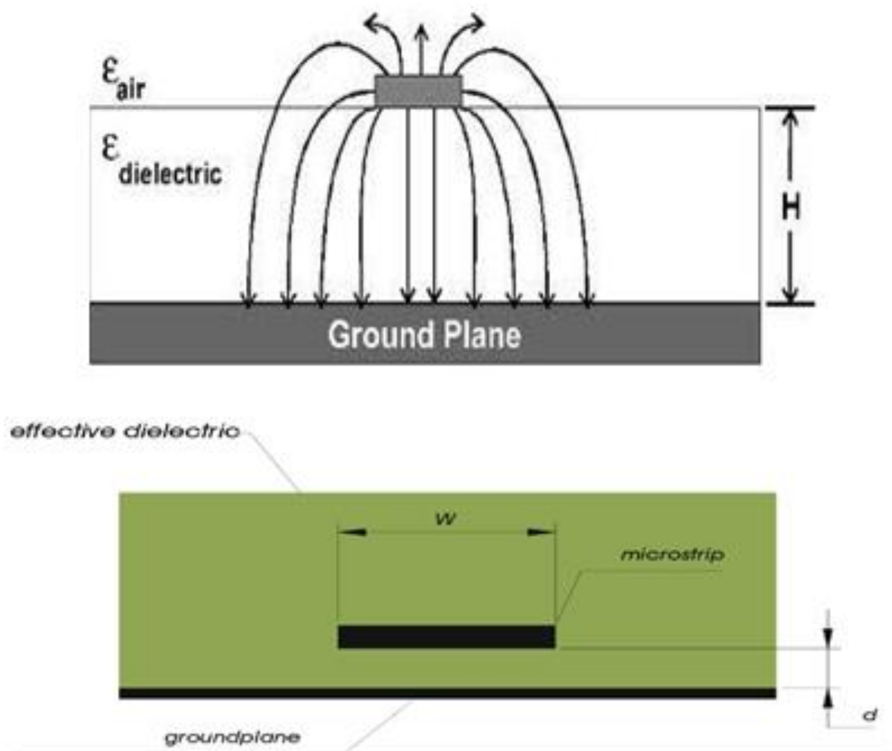


Figure 2.1 Microstrip E- field lines and its dielectric constant

2.5 ADVANTAGES AND DISADVANTAGES

ADVANTAGES

1) Low weight and fabrication cost is less

2) supports both, linear as well as circular polarization.

3) Can be easily integrated with microwave integrated circuits.

4) Capable of dual and triple frequency operations.

5) Mechanically robust when mounted on rigid surfaces.

6) low profile antenna.

7) High performance.

DISADVANTAGES

1) band width is narrow

2) Low Gain and efficency

3) Low power handling capacity.

4) Surface wave excitation

5) irregular size

6) more complexity

CHAPTER 3

ANTENNA DESIGN

3.1 INTRODUCTION

It is found that the important motto in modern communication systems is the design of wide band, low profile and very small antennas. After a long antenna research, many found that the fractal antennas can fulfill these requirements, fractal antennas is a new concept which is not studied earlier.

It is defined as a geometric shape that repeats and take shape over and over.

These fractal shape antennas are used particularly in computer modeling of irregular patterns and structures in nature. It is found that these are approximately 20% more efficient than normal shaped antennas.

These are used for space filling of regular or irregular shapes. The features of fractal antenna are self similar, simple, recursive, irregular. Long ago various fractal concepts are initiated for antenna applications for improving antenna characteristics. Some of these concepts are mostly size reduction of antenna, where the other designs are mostly for multiband characteristics. These are used as multitasking antennas which are known as low profile antennas with a medium gain. In my present work to increase the bandwidth and reduce the size of antenna, a plus shape patch is considered as a base shape and during the first iteration four plus shape patches of order 1/3 are introduced which touches the base shape and after the completion of first iteration, similarly second iterations are introduced by placing same plus shaped patches but at uniform reduced sizes. It is observed that the resonant frequency decreases as the iteration number increases which represents a new plus shape patch.

3.2 DESIGN ANALYSIS

In the design of a plus shape antenna, first we have to design a base shape of it. Base shape antenna is designed on a dielectric substrate having dielectric constant 4.4 and a thickness of 0.05 mm. as illustrated in **figure4.1**. This is known as reference antenna. After that it is modified by inserting horizontal slots on both sides w.r.t the center of the patch illustrated in **figure 4.2** and it penned as antenna with slots.

As the length of the slot Ls is differed starting from 2.5mm to 21.785mm and resonance frequency is achieved. Space between the slots is q=2mm is used for the next designs excluding the base shape. The effective length obtained is Ls= 21.785mm and the effective design dimensions are **table 1** . The ground plane dimensions are taken as 50mm * 80mm. A 50 ohm SMA connector is used to feed the antenna. The dimensions are **table 1** .These design parameters are simulated in CST microwave studio 12.0 and better results are attained. The simulated figures and actual rough diagrams shown in next coming pages.

TABLE 1

	BASE SHAPE	BASE SHAPE WITH SLOTS	FIRST ITERATION	SECOND ITERATION
a	44.8mm	44.8 mm	44.8mm	44.8 mm
b	14.93mm	14.93 mm	14.93mm	14.93 mm
c	35.0mm	35.0 mm	35.0mm	35.0 mm
d	11.67mm	11.67 mm	11.67mm	11.67mm
e			14.93mm	14.93mm
f			4.97mm	4.97mm
g			11.67mm	11.67mm
h			3.89mm	3.89mm
i				4.97mm
j				1.66mm
k				3.89mm
l				1.29mm
m	0.45mm	0.45 mm	0.45mm	0.45mm
n	18.50mm	18.50 mm	18.50mm	18.50mm
o	3.10mm	3.10 mm	3.10mm	3.10mm
p	17.9mm	17.9 mm	17.9mm	17.9mm
Ls		21.785mm	21.785mm	21.785mm
q		2mm	2mm	2mm
Ws		2mm	2mm	2mm

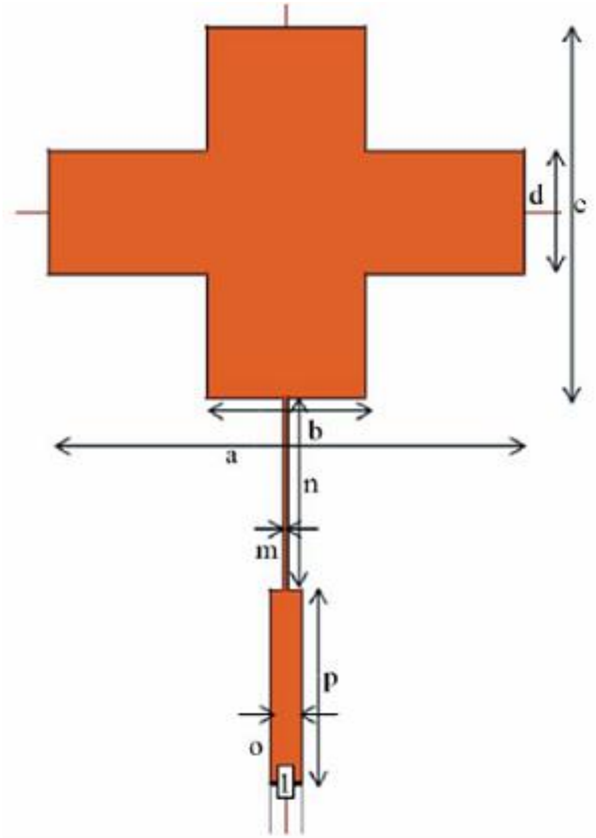


FIGURE 4.1 BASE SHAPE ANTENNA

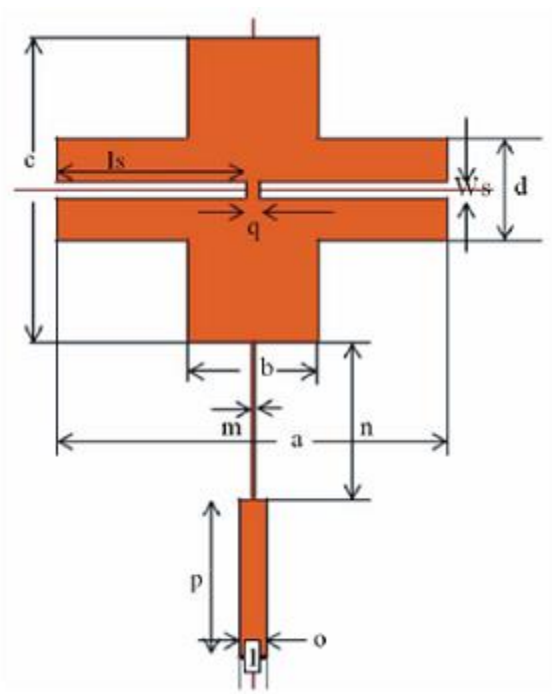


FIGURE 4.2 ANTENNA WITH SLOTS

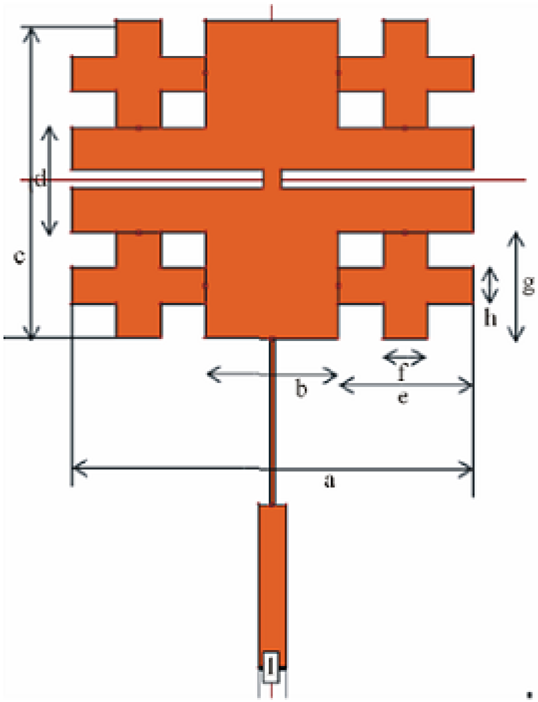
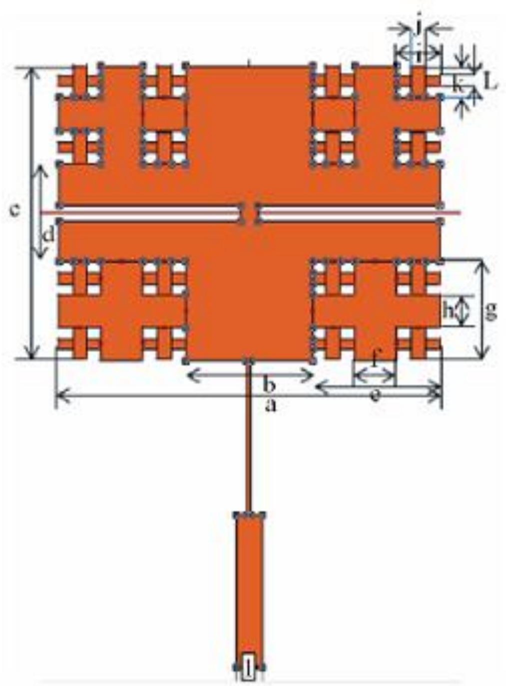


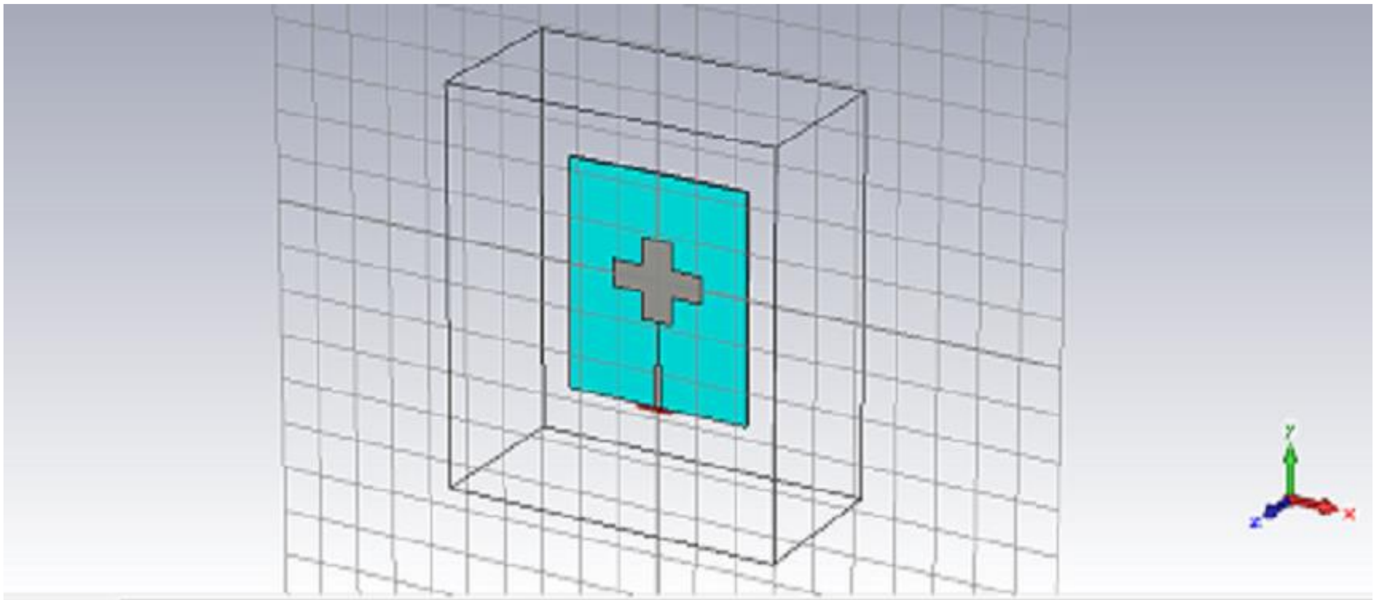
FIGURE ANTENNA FOR 1ST ITERATION

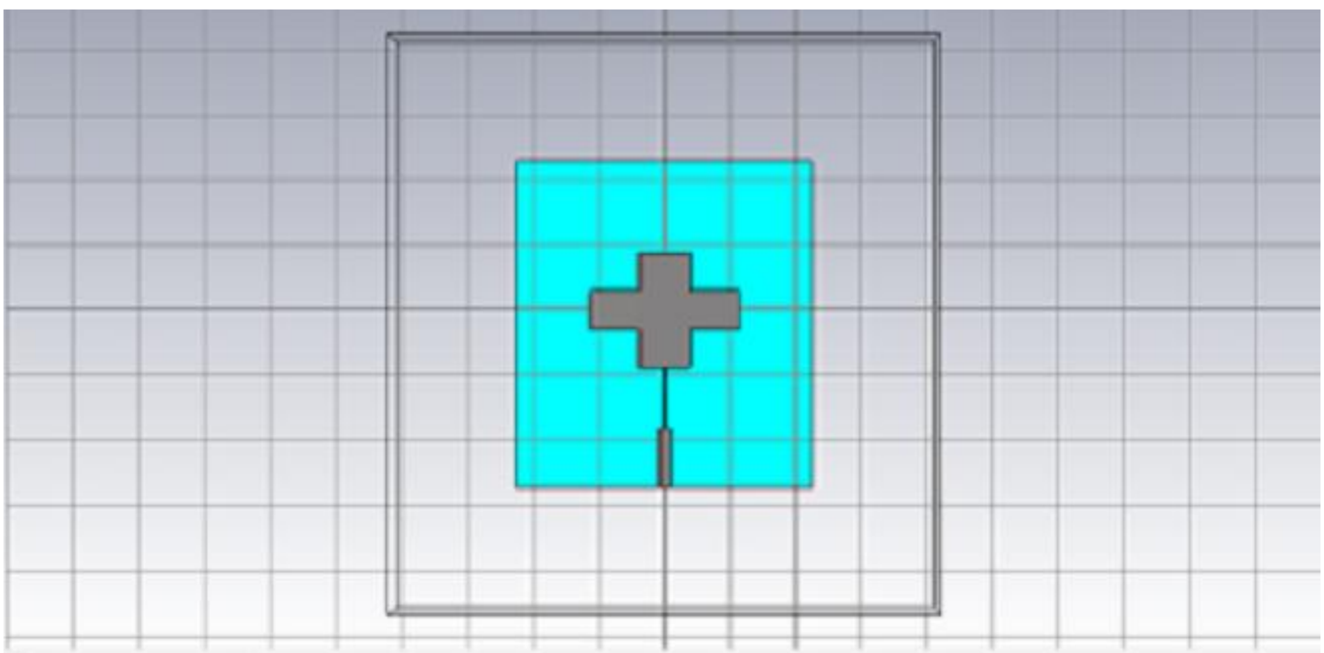


22 FIGURE ANTENNA FOR 2ND ITERATION

3.3) SIMULATED DIAGRAMS: 1a) base shape antenna

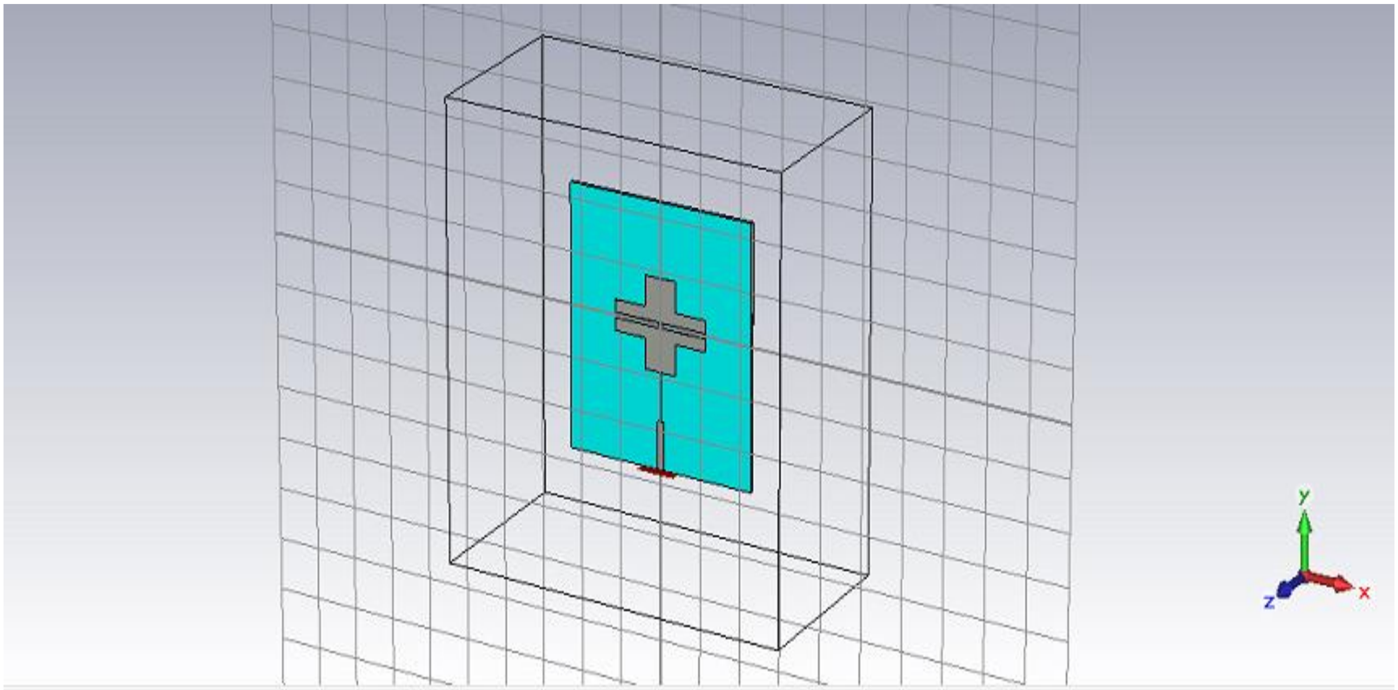
1b) front view of base shape antenna

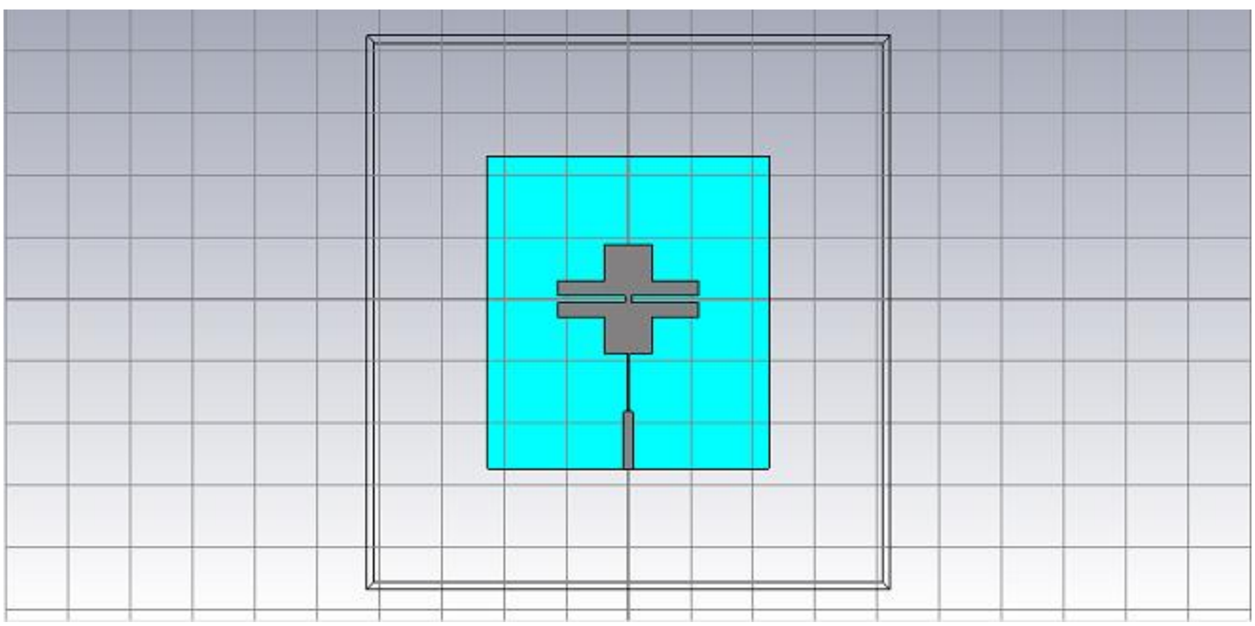




2a) base shape antenna with slots

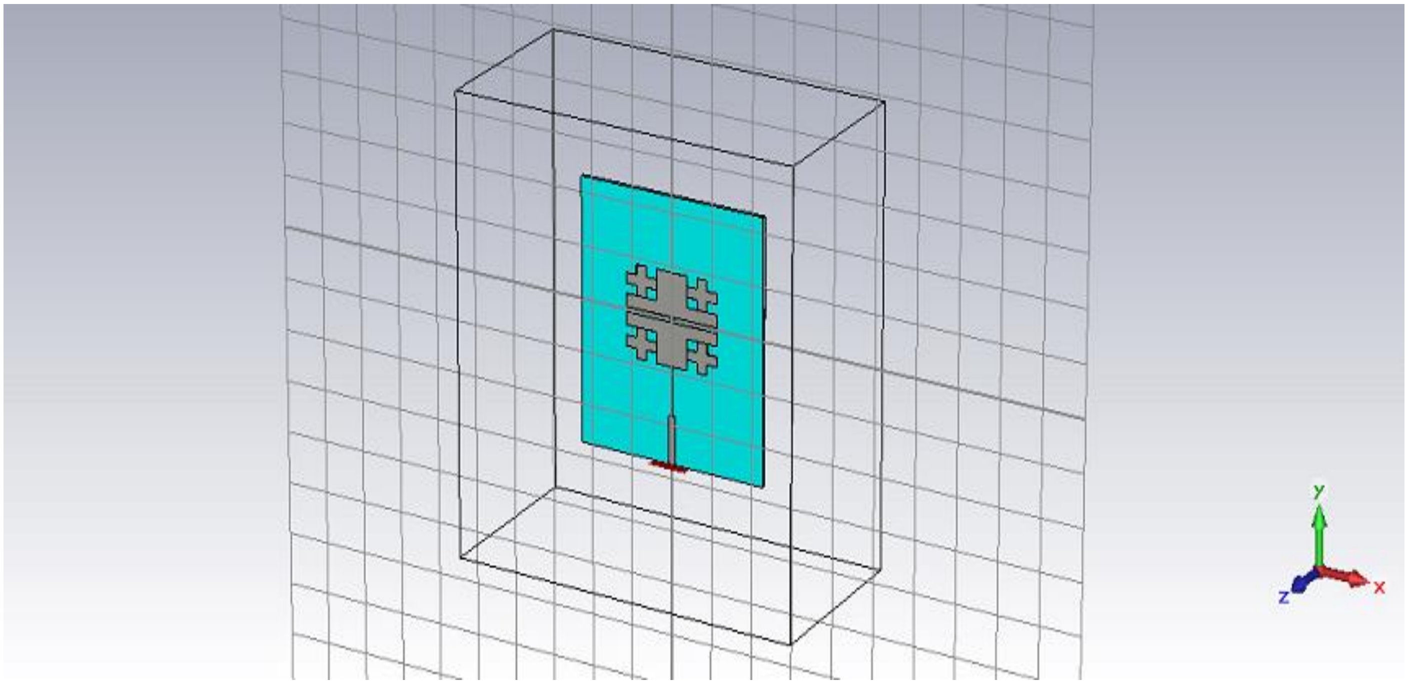
2b) its front view

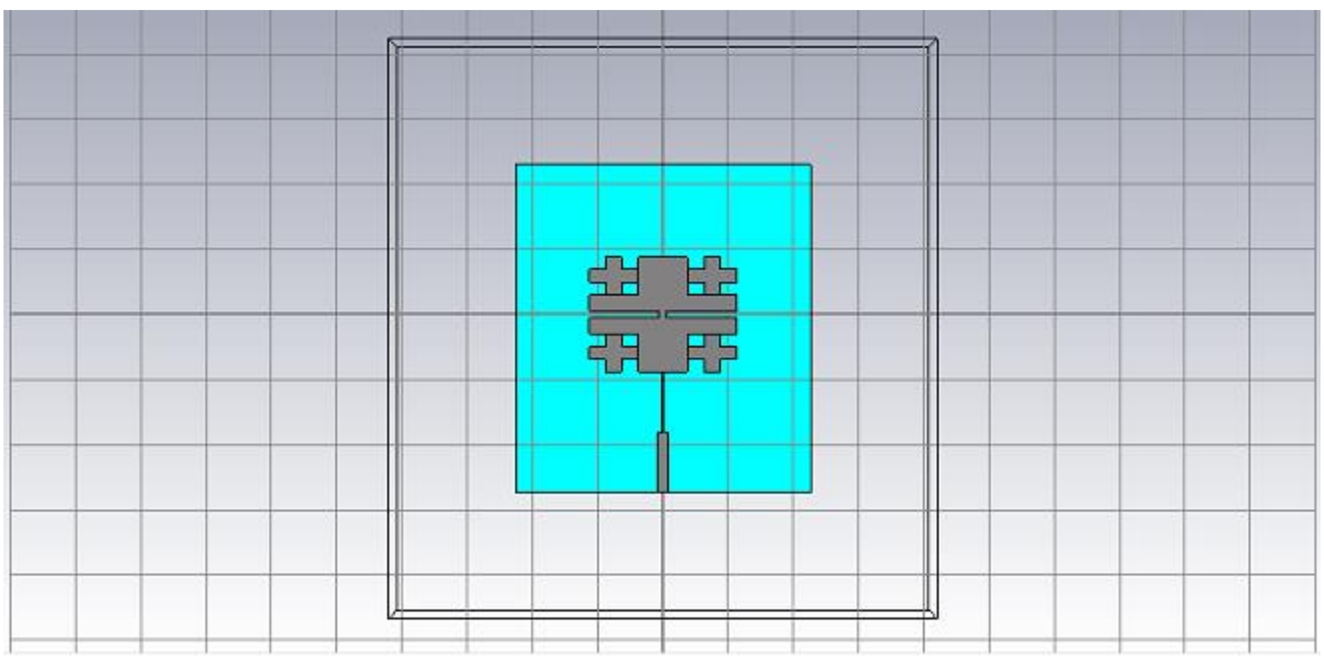




3a) antenna with 1st iteration

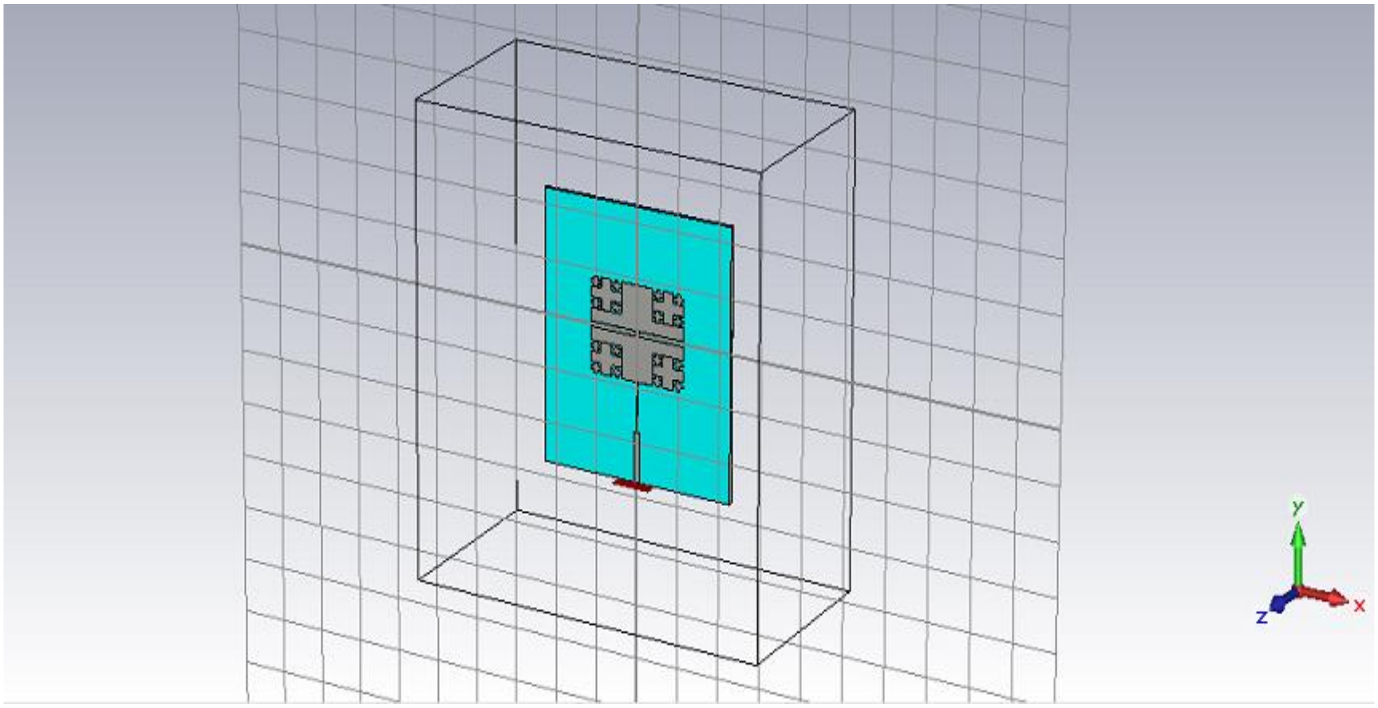
3b) its front view

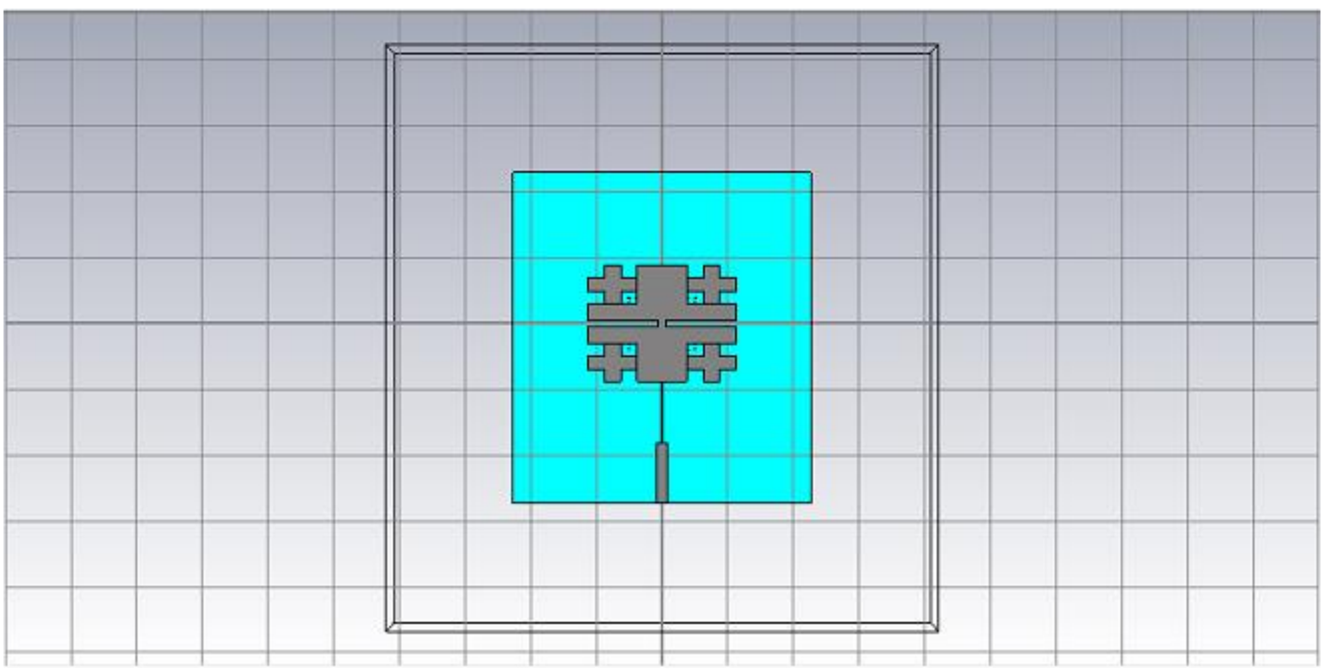




4a) antenna with 2^{nd} iteration

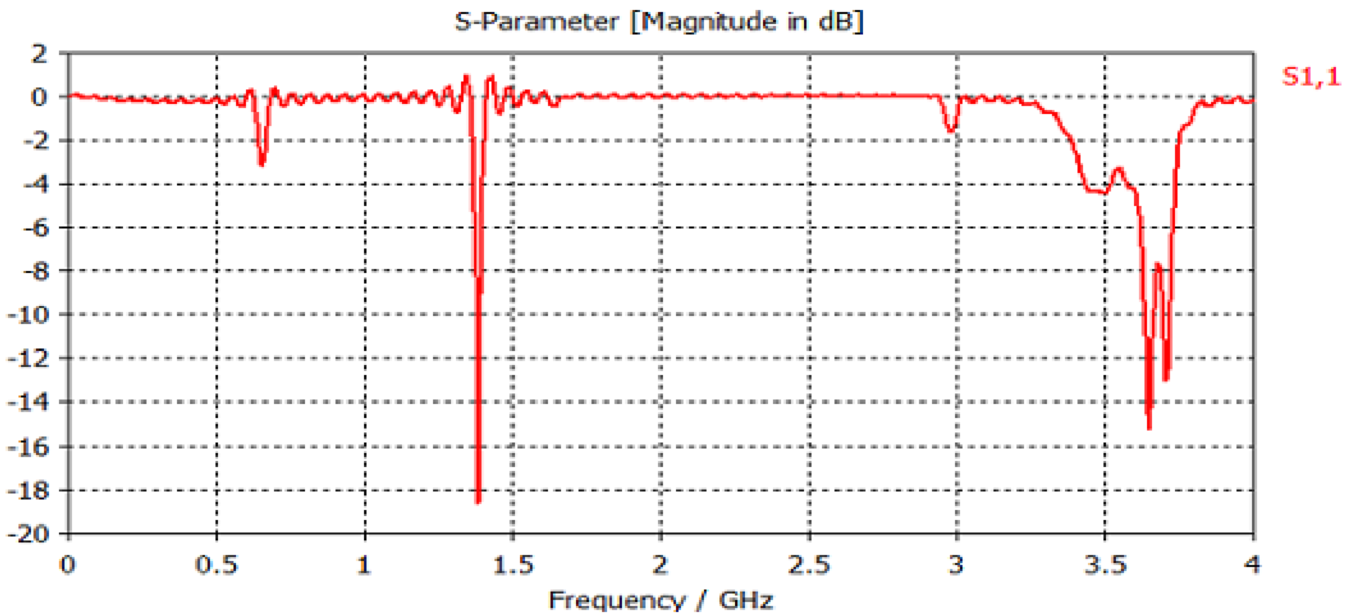
4b) its front view

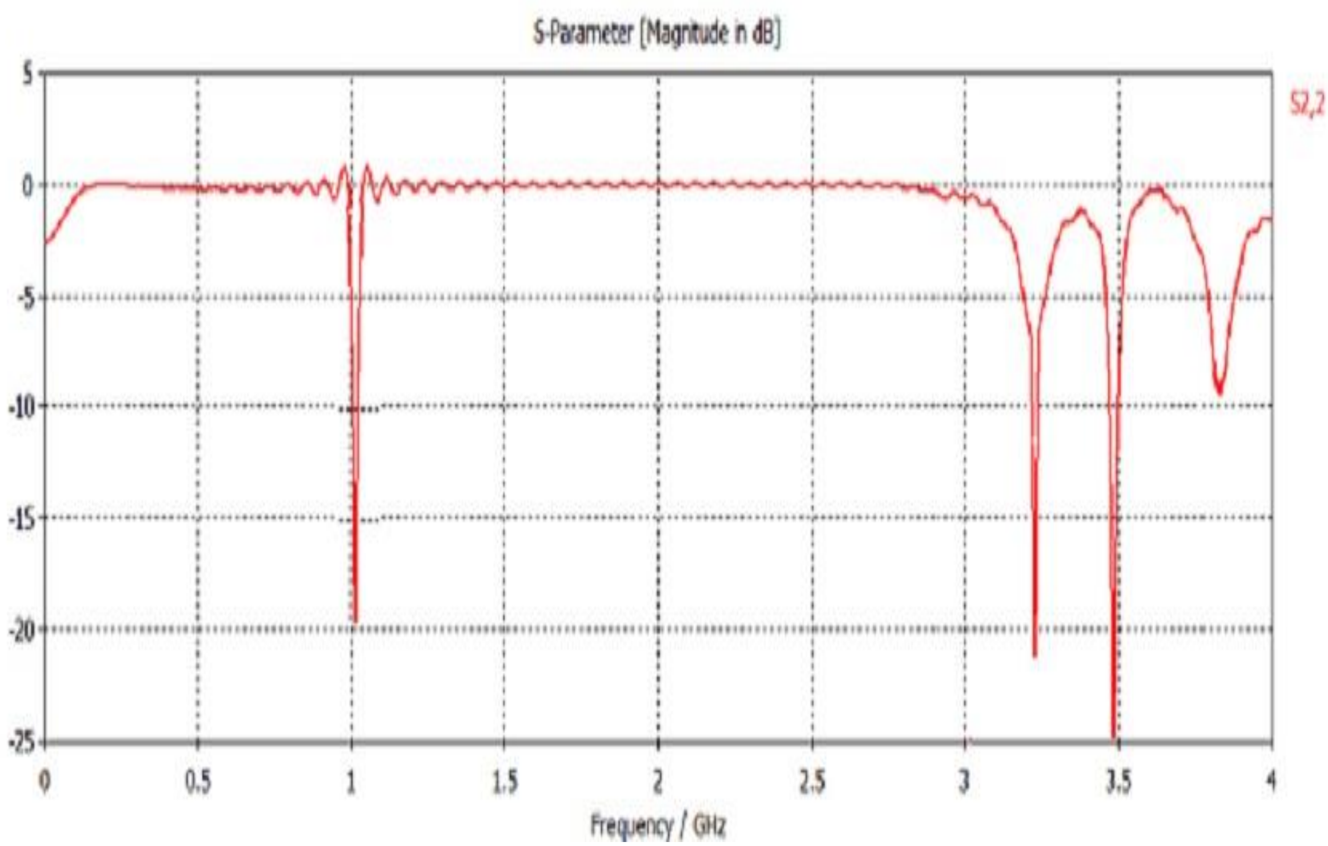




5a) Return loss characteristics of 1st iteration with q=2mm

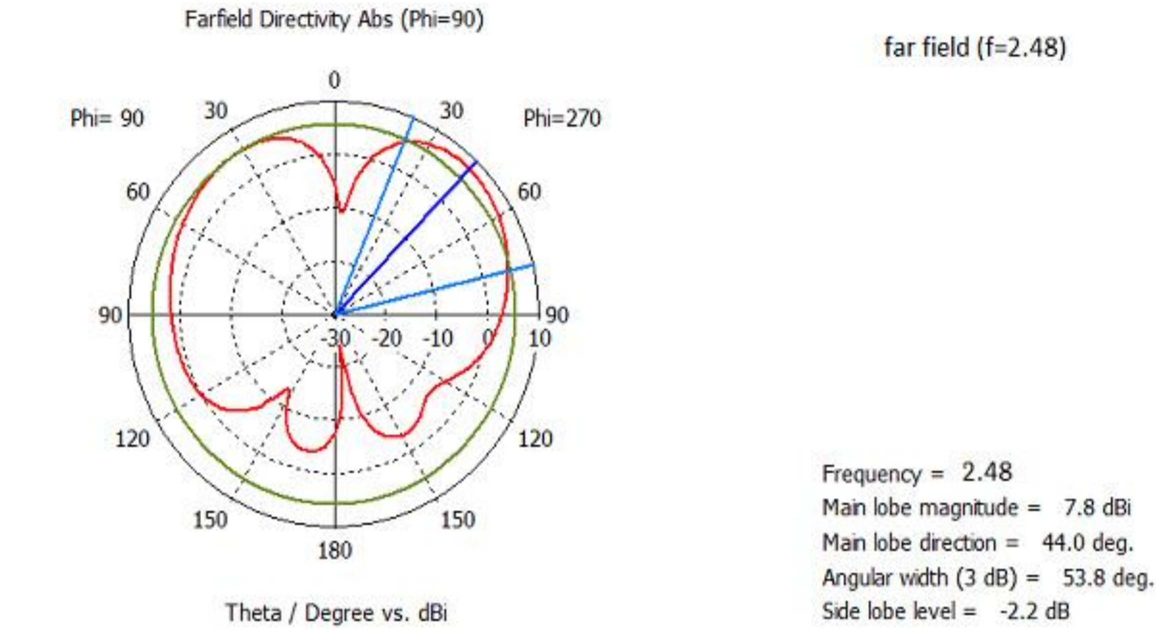
5b) Return loss characteristics of 2nd iteration with q=2mm

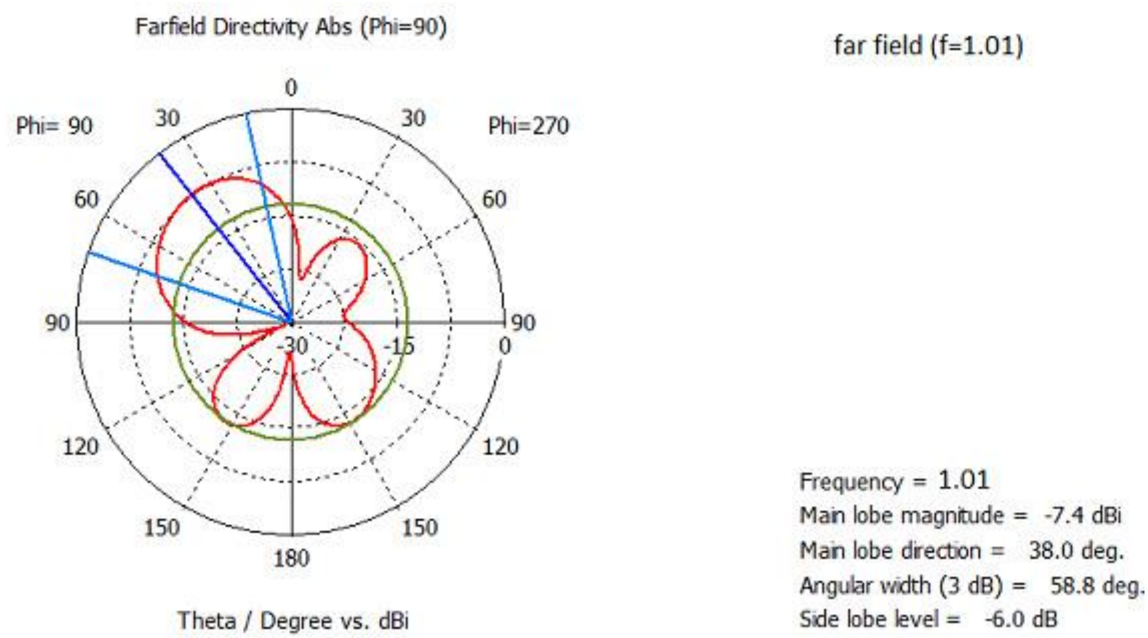




6a) Radiation pattern of base shape at 2.48 Ghz

6b) Radiation pattern of second iteration at 1.01 Ghz





3.4 Advantages and Disadvantages of fractal antenna

ADVANTAGES

1) Size can be shrunk from two to four times with surprising good performance.

2) Multiband performance is at non-harmonic frequencies.

3) Compressed resonant behaviour.

4) Improved reliability

5) Reduced construction costs.

6) Polarisation and phasing of FEA also are possible.

DISADVANTAGES

1) Low Gain

2) Too complex geometry

3) Numerical Limitations

4) Practically only few iterations are possible to design, after that benefits start to diminish.

3.5 CALCULATIONS:

<u>For 2nd iteration</u>

Lower cut off frequency f1= 3.45Ghz

Upper cut off frequency f2= 3.5Ghz

% Bandwidth= {2(f2-f1) / (f1+f2)} * 100

= 0.1438 * 100

= 14.38%

What we got is actually fractional bandwidth but it also considered as a band width.

<u>For 1st iteration</u>

Lower cut off frequency f1= 3.67 Ghz

Upper cut off frequency f2= 3.7 Ghz

% Bandwidth= {2(f2-f1) / (f1+f2)} * 100

= 0.11055 * 100

= 11.05%

Comparing first and second iterations, it is found that the bandwidth increases from 11.05% to 14.38%.

CONCLUSION

In this thesis the fractal antenna characteristics with slot and with iterations and the bandwidths of proposed antennas has been studied through simulation by using CST Microwave Studio Suite 12. After first and second iterations, a new plus shape slotted fractal antenna is designed. The slotted fractal antenna after second iteration gives increased band width of 14.38% when compared to first iteration which gives band width of 13.42% and a size reduction of 59.27% and with radiation pattern. Size reduction can be found by the total area of the antenna used. Resonant frequency decreased from 2.48 Ghz to 1.01 Ghz. Finally from the results it is concluded that the attained base shape antenna with slots of second iteration gives a fair size reduction and increased band width when compared with the modified base shape antenna with slot of first iteration. These antennas may find different applications in wireless communication systems, for example in personal hand-held wireless devices such as cell phones and other wireless mobile devices such as laptops on wireless LANs. It is used in radios, radars, dish antenna, cars.

FUTURE WORK

As we have the design parameters of plus shape antenna and are simulated in CST for which we observed that the bandwidth is increased and we got better results. Thus , with the design parameters we can fabricate a plus shape antenna with ease of cost as the antenna size is compared to normal antennas.

REFERENCES

1. https://www.wikipedia.org
2. https://www.google.com
3. www.antennatheory.com.
4. Constantine A. Balanis, “Antenna Theory - Analysis and Design”, John Wiley & Sons, Third edition, Inc 1997
5. MIMO Fractal antennas: For wireless communications by Ali Jabbar Salim, Adil Hameed Ahmad, Raad Sami Fyath
6. D. M. Pozar and D. H. Schaubert, Microstrip Antennas, “The Analysis and Design of microstrip Antennas and Arrays”, IEEE Press, 1995
7. www.instructables.com
8. Design and aimulation of Fractal antenna for WLan by Gurjot Singh Gaba and Paramdeep Singh
9. K.Falconer, Fractal Geometry: Mathematical foundations and applications, John Wiley and sons, New York, 1990.
10. B.B Mandelbrot, The Fractal Geometry of Nature, Freeman, 1983.
11. Theodore S. Rappaport, “Wireless communications, Principles and practice”, second edition.
12. Garg, R., Bhartia P, Bahl I., Ittipiboon A., “Microstrip Antenna Design Handbook”, Artech House, Inc, 2001.
13. J. G. Proakis, Digital Communications, New York: McGraw-Hill, 1989.